Future and Emerging Computing Paradigms and Machines

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After more than 50 years of exponential computing power growth under Moore's law, sequential computing as we know it is increasingly hitting a wall, mainly because of fundamental physical limits, economical considerations, and reliability issues because of miniaturization. In order to understand, model, predict, and simulate tomorrow's natural and man-made complex systems, we need computer science and computer engineering to keep going at least at the same pace, which requires massive investments in radically new machines, paradigms, and models of computation.

The 21st century promises to be the century of cognitive, bio, nano, and information science [1]. We are interested in future and emerging computing paradigms and machines that will enable us to 1) go beyond the horizon of silicon-based top-down engineered electronics, and 2) open new and previously unexplored application areas and environments for information-processing devices, such as invisible and undetectable electronics based on bio- and nano-molecules or randomly assembled systems that are extremely hard to reverse engineer.

Molecular self-assembly is often mentioned as the holy grail of nanotechnology, which allows us to easily and cheaply build systems of enormous complexity. The grand challenge consists of using this functional and structural complexity for performing efficient communication and computations.

Our work, which combines theory, simulations, and experiments, goes far beyond other approaches [2,3] for novel interconnects. We have taken an extremely fabrication-friendly stance of building novel computing machines by building functional structures that we can very easily and cheaply self-assemble, without having to worry about the device's reliability, regularity, or homogeneity. The first steps solely focused on interconnectivity issues because the interconnect is today's limiting factor of performance on electronic chips.

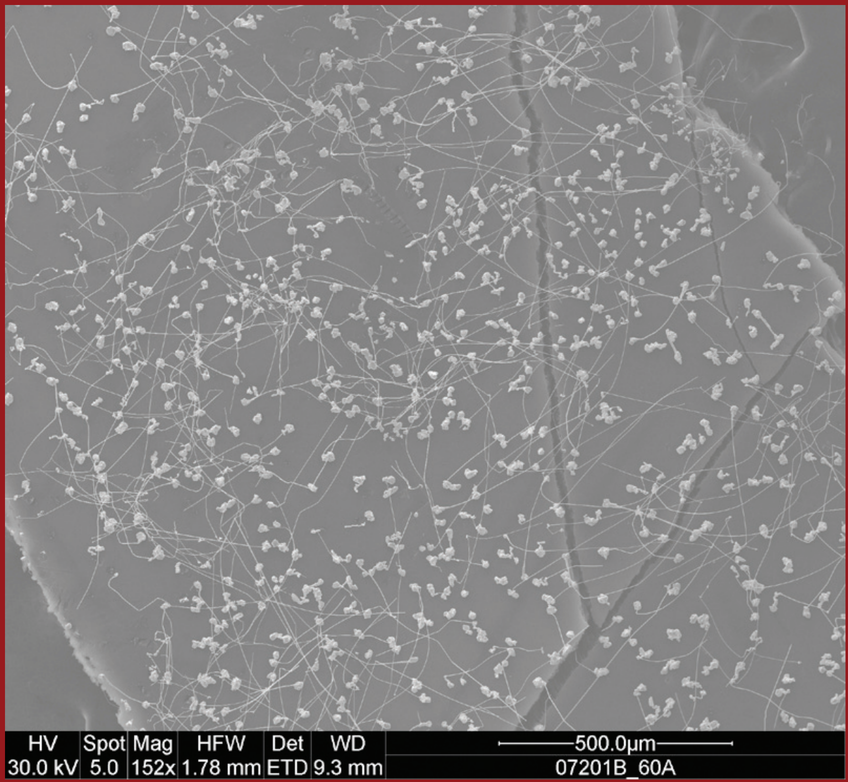

Fig. 1. Self-assembled nanowires fabricated at LANL. Image courtesy: Hsing-Lin Wang.

Nanowires can be grown in various ways using diverse materials such as metals and semiconductors. We have demonstrated that Ag nanowires can be fabricated on top of conducting polymer membranes via a spontaneous electrodeless deposition (self-assembly) method [4,5] (Fig. 1 shows a prototype of such an assembly). We will use such wires to densely interconnect computing nodes. On the theoretical side, we have shown that such irregular, nonclassical, and self-assembled interconnects can have superior performance and robustness over regular assemblies [6,7].

Our interdisciplinary and integrated approach in both the experimental and theoretical aspects opens novel perspectives on future information processing devices. With a better understanding of the relevant design trade-offs, the fabrication issues, and the communication and computing aspects, our research represents a significant step towards building alternative, more complex, bottom-up fabricated information processing devices in a cheaper and ultimately simpler way. We argue that mastering these future and emerging technologies is critical for the Laboratory to remain a world leader in computing.

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